Continuous Evaluation of Fast Processes in Climate Models Using ARM Measurements

A major CCPP effort to fully utilize ASR measurements to a new level

(Yangang Liu and 20 Co-Investigators)

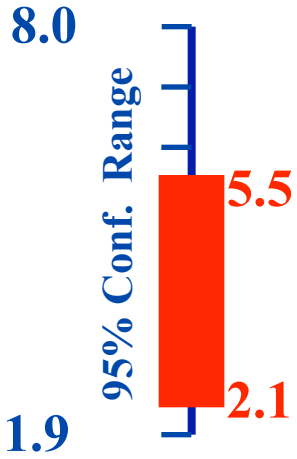
Common feature of the three logos: they all have clouds; the rare phoenix cloud in the middle reflects problem complexity/difficulty, project longevity, and close/fast inter-program connections.

CMWG-AWG
Boulder, 9/30/2009

Brookhaven Climate Consortium

BROOKHAVEN NATIONAL LABORATORY

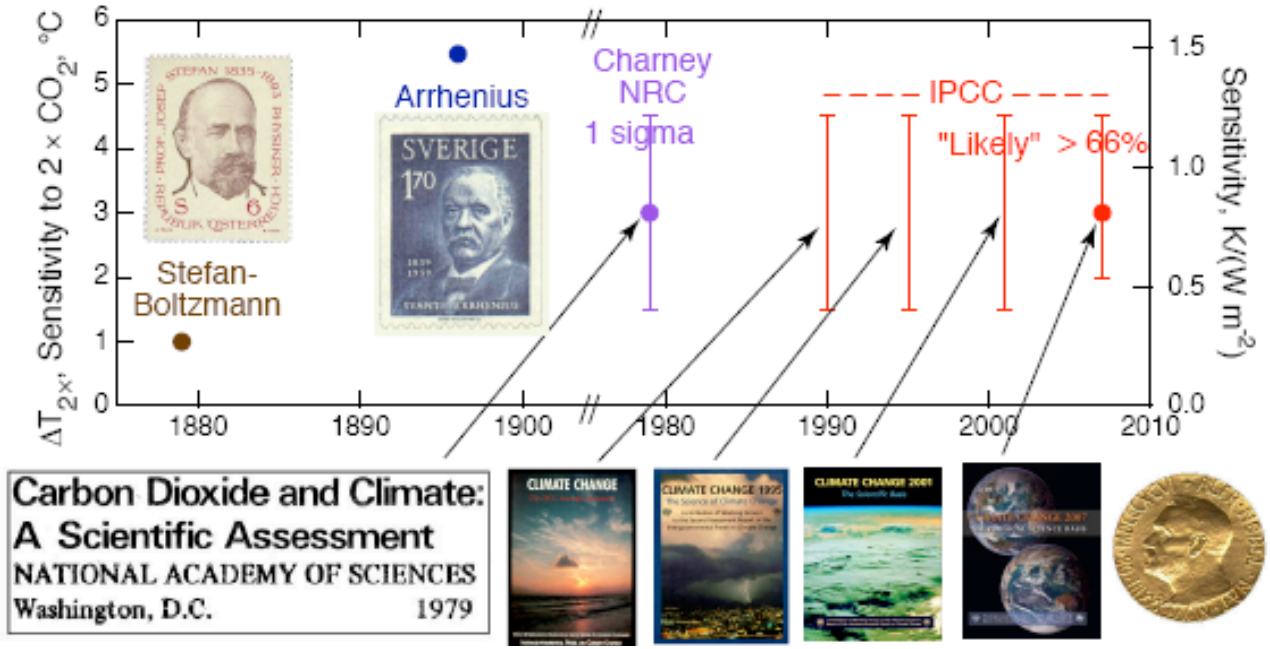
Research has progressed, but the pace has been frustratingly slow!



(Huybers, 2009)

Virtually Unchanged Large Uncertainty of Model Climate Sensitivity through Ages

(Adapted from Schwartz 2009)



Wide spread has been related to parameterizations of cloud-related fast (subgrid) processes.

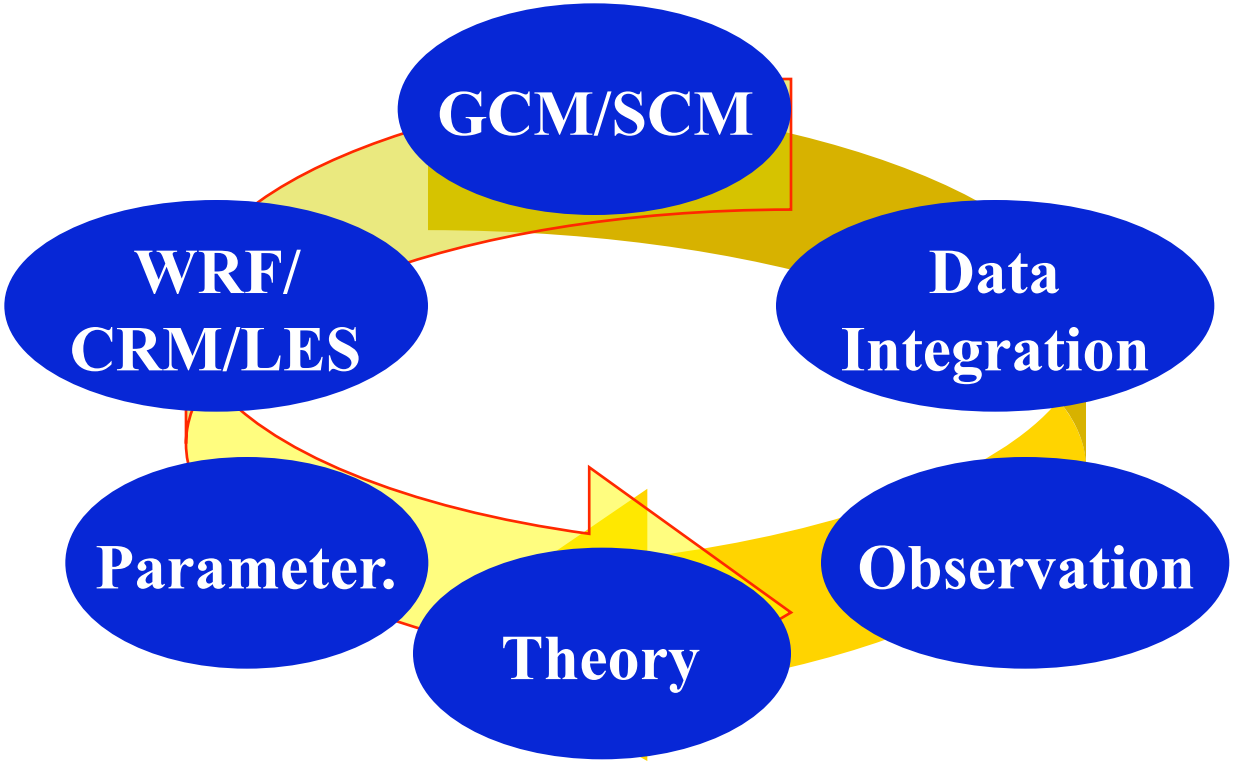
The sheer complexities of the problem are certainly a reason for the slow progress.

Complexities:

- **Scientific**
  - -- Conceptual
  - -- Numerical
  - -- Coupling

(Recall Randall's Tues talk)

- **Technical/logistic**
  - -- Inter-field interactions
  - -- Para. imple. in GCMs
  - -- ….



Randall et al. (BAMS, 2003): "A model-evaluation project is complicated in at least two distinctive ways. The technical complexities are obvious and daunting: Data must collected and analyzed, …. An additional and equally complex task is to foster communication and fruit interactions …."

Issues well recognized, great efforts made, and progress realized; now is the time to do more 

Acceleration of progress demands more focused and concerted efforts.

Randall's answer to **Lamb's question on slow progress Tues. am:** ***need more systematic focused evaluation (paraphrase)!***

Four Complementary Evaluation Approaches:

- **Brute force full-GCM (slow) -- Focused by IPCC**
- **GCM in forecast mode (faster than IPCC) -- Focused by CAPT**
- **SCM enhanced with CRM/LES modeling (fast and repeatable) -- Organized in ARM/GEWEX; Focused by KNMI SCM-testbed**
- **Available NWP forecast, analysis and reanalysis (NWP-testbed) – Focused by European Cloudnet project (fast but not easy to rerun)**

There are less focused efforts in SCM-testbed and NWP-testbed in US, and this project is to fill this critical need to build a Fast-Physics Testbed by synthesizing SCM-testbed and NWP-testbed approaches and enhancing them via a suite of other activities, and perform continuous model evaluation against comprehensive, long-term ASR measurements.

Now
is the time for this "ARM-like innovation".

Now is the time

- **ARM has made continuous, comprehensive, decade-long measurements, permitting better statistics, more cloud types, weather regimes ….**
- **SCM/CRM/LES approaches have been well developed and tested by ARM scientists and others.**
- **A smaller scale-SCM-testbed has been recently established by Dr. Neggers et al. at Netherlands**
- **Usefulness of NWP-testbed has been demonstrated by Cloudnet project.**

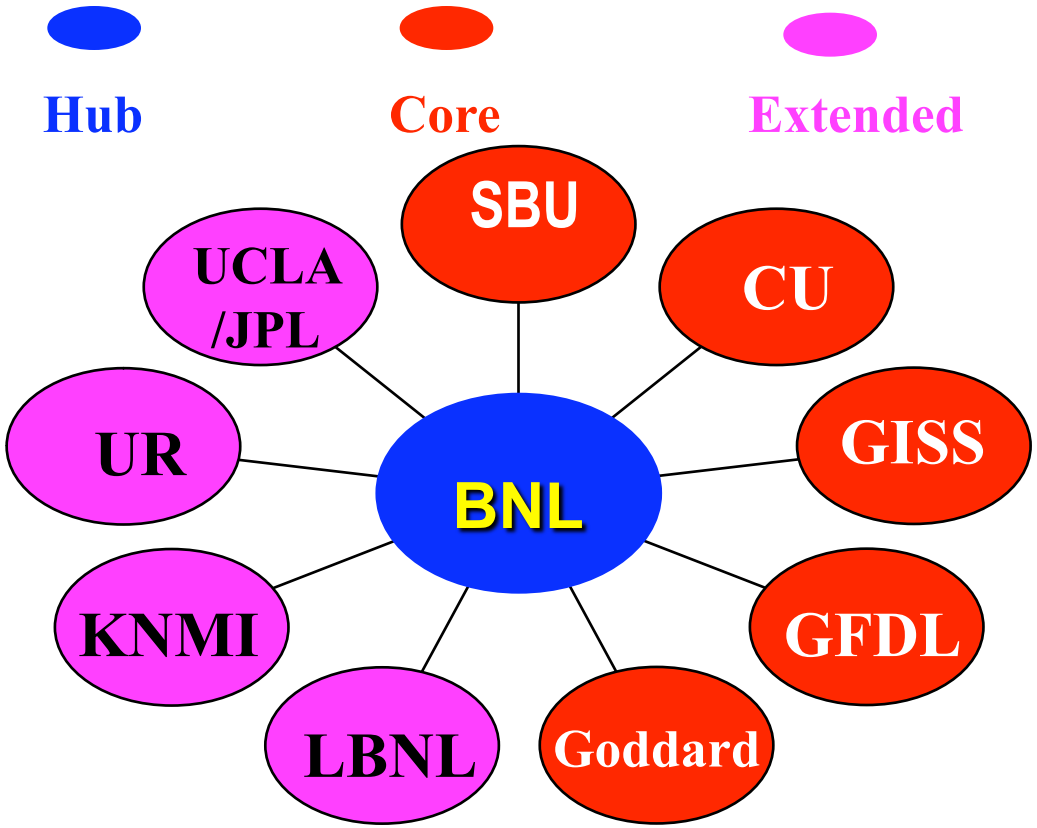
ARM-Like Innovation

Ackerman and Stokes on ARM's Innovation (Physics Today, 2003): " …. Even before ARM, scientists had already made such efforts in field campaigns that lasted for a month or two. ARM's unique innovation was to perform the measurements continuously for a decade or more …."

To paraphrase: …. This project's unique innovation is to perform the evaluation continuously for a decade or more and in a more focused way ….

Formation of Brookhaven Climate Consortium (BCC) to Overcome Technical/Logistic Complexity

BCC (10 institutions and 21 scientists)



Investigator	Institution
Yangang Liu	BNL
Stephen Schwartz	BNL
Warren Wiscombe	BNL/Goddard
Robert McGraw	BNL
Wuyin Lin	BNL
Andrew Vogelmann	BNL
Michael Jensen	BNL
Richard Wagener	BNL
Dong Huang	BNL
Wei Wu	BNL
Surabi Menon	LBNL
Susanna Bauer	CU
Minghua Zhang	SBU
Marat Khairoutdinov	SBU
Anthony Del Genio	GISS
Ann Fridlind	GISS
Yonghua Chen	CU
Leo Donner	GFDL
Zhijin Li	UCLA/JPL
Robin Hogan	UR
Roel Neggers	KNMI

(1) Four institutions (core) are adjacent to BNL and operate three major US GCMs and their SCMs, providing unique opportunity for concerted interactions and quick implementation of improved parameterizations. (2) Most team members have participated in ASR, forming a tighter microcosm key to the project success.

Project has one overarching goal, six objectives, and eight major tasks.

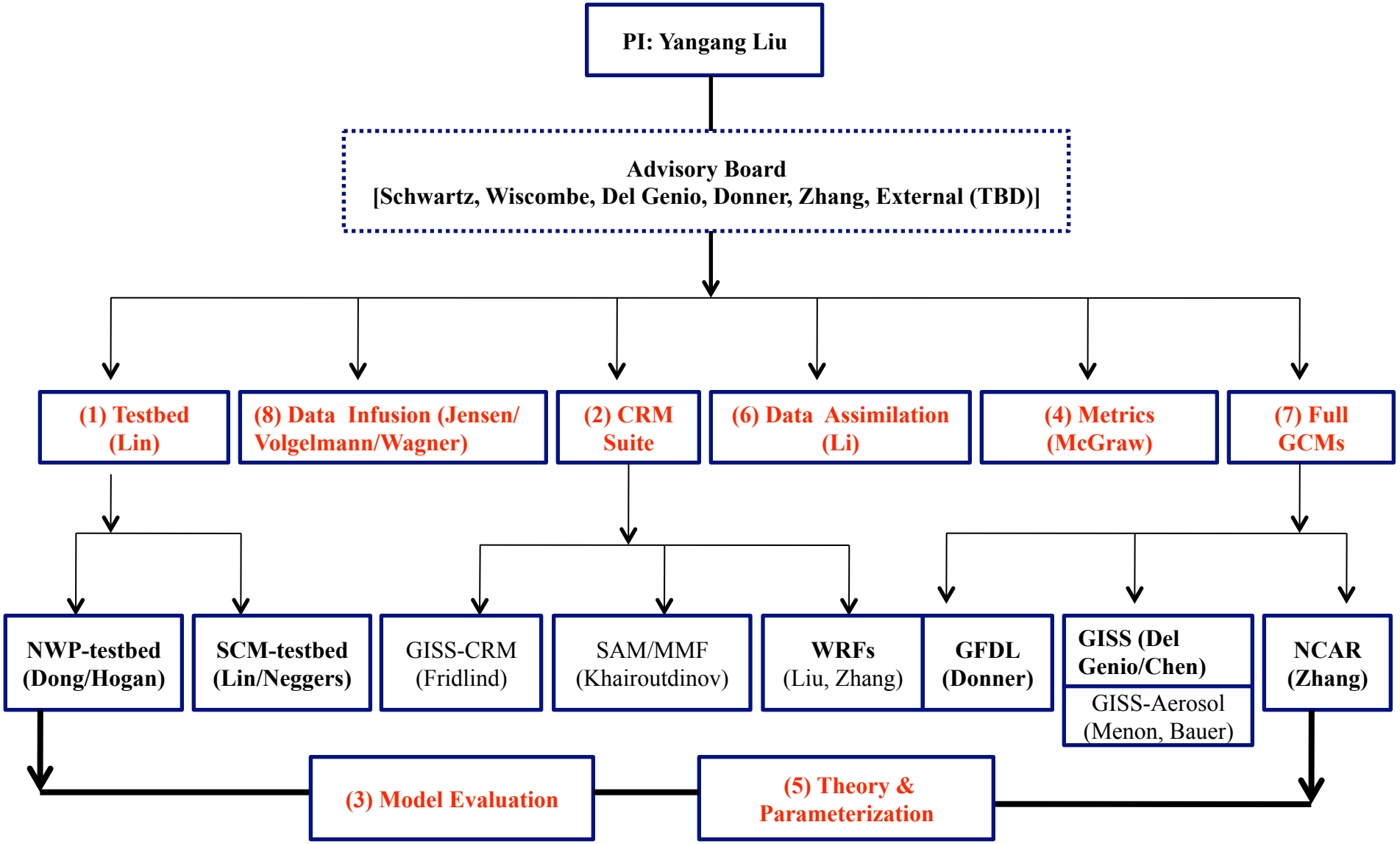
One Goal: Utilize *continuous long-term* ARM measurements to *enhance/accelerate* evaluation/improvement of parameterizations of fast processes in GCMs and narrow GCM uncertainty and biases.

Six Objectives:

- **Construction of a fast-physics testbed**
- **Execution of a suite of CRM/LES simulations**
- **Evaluation of model performance**
- **Examination and improvement of parameterizations**
- **Assessment and development of evaluation metrics**
- **Incorporation of acquired knowledge into the full GCMs**

Eight Major Tasks

Eight Major Tasks and Management



All scientists work closely together, with focused areas identified. All scientists participate in (3) and (5) with different focused processes/aspects.

Work Plan

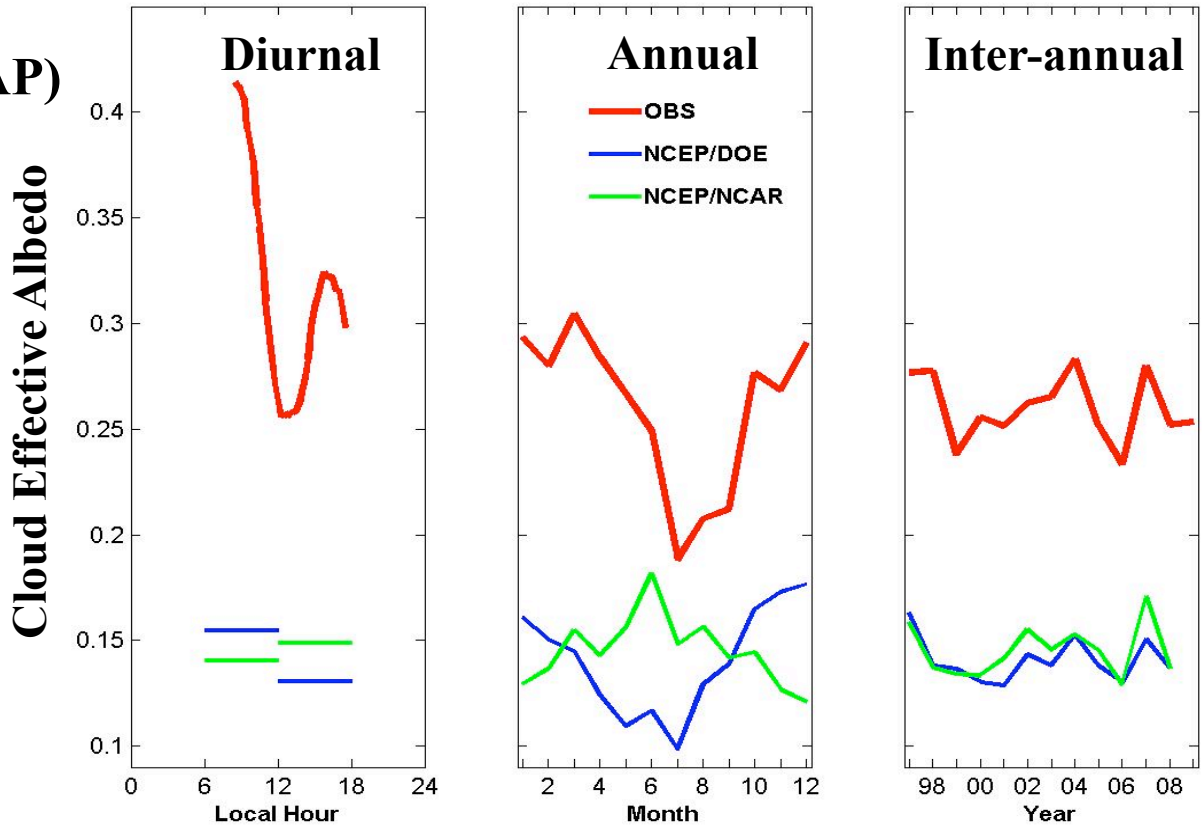
- **Preparation stage: new hires, testbed hardware/logistics, ... (where we are now)**
- **NWP-testbed focused on SGP & SCM-testbed focused on well studied IOP cases at SGP to make sure its proper working**
- **In-depth high-resolution modeling & more retro-SCM evaluations**
- **Expansion of similar activities for SGP to the other sites**
- **Upgrade the testbed from retro-evaluation mode to real-time mode, open the fast physics testbed to no team members, and include other SCMs in addition to NCAR, GISS and GFDL**
- ***Long-term hope: to make the fast-physics testbed a quasi-real time model evaluation facility***
- ***Fast-physics testbed will evolve as GCMs and NWP progress.***
- ***Work closely with other complementary activities such as CAPT, ARM data development (e.g., ARSCL, Microbase, CMBE, RIPBE), CCPP activity, BNL data mining/visualization, ….***

Progress 1: SGP Effective Cloud Albedo and Observation-Reanalysis Comparison

- **Long-term radiation measurement (Long's VAP)**
- **Minimizing non-cloud effects**
- **Effective cloud albedo (Betts, 2009):**

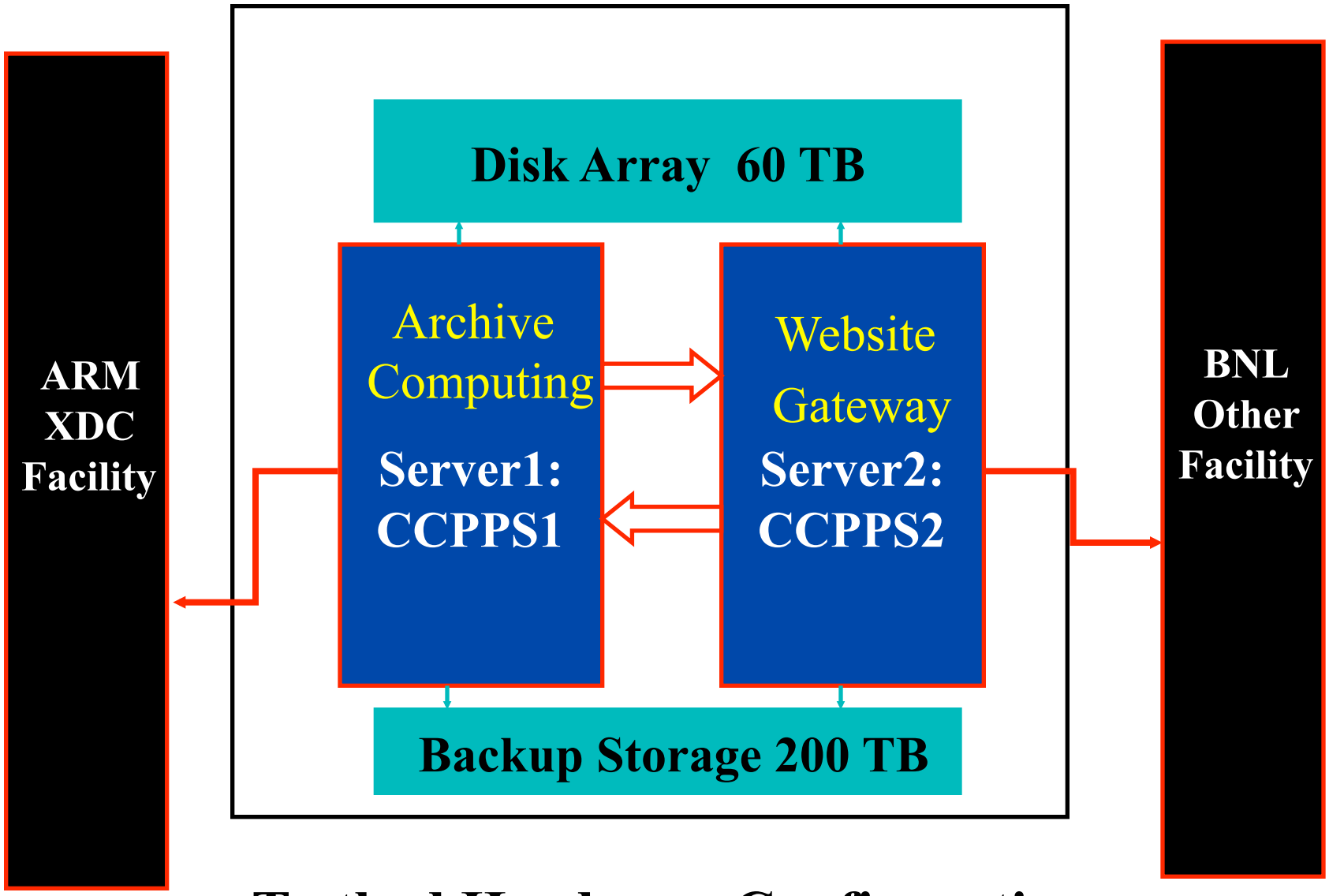
$$\alpha_e = \frac{F_{clear} - F_{all}}{F_{clear}}$$

- **Derived long-term cloud effective albedo data since 1997**



This diagram compares diurnal, annual, and inter-annual variations of effective albedo derived from radiation measurements (red), NCEP/DOE reanalysis (blue), and NCEP/NCAR reanalysis (green). Both reanalyses capture the inter-annual pattern well, but strongly underestimate. NCEP/DOE catches the annual variation better than NCEP/NCAR. → *cloud fraction, albedo, and NWP usefulness*

Progress 2: BBC Fast-Physics Testbed

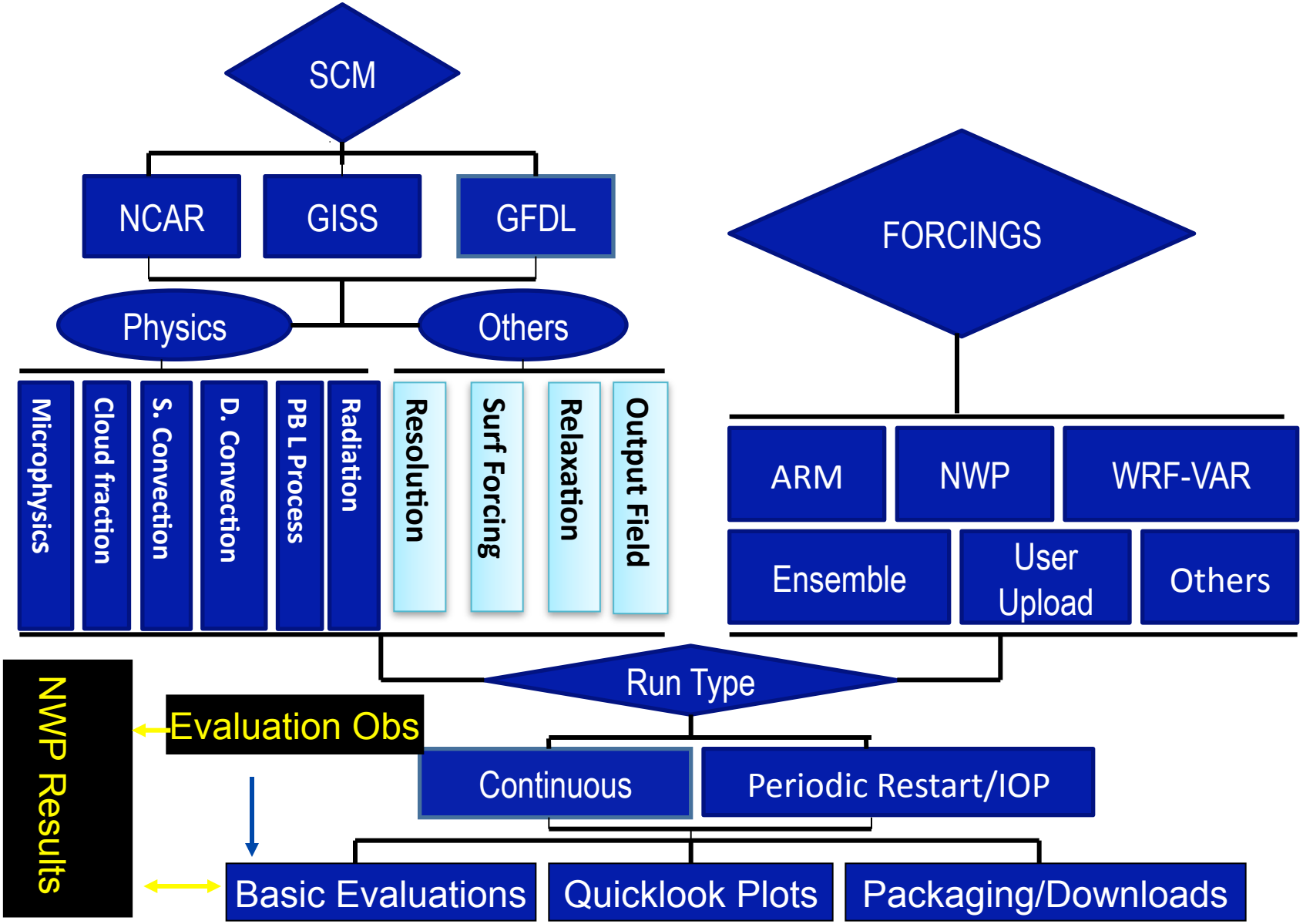


Testbed Hardware Configuration

Progress 3: Project Gateway – Website

Thanks; comments and suggestions?

SCM-Testbed Flow Chart



NWP-Testbed Flow Chart

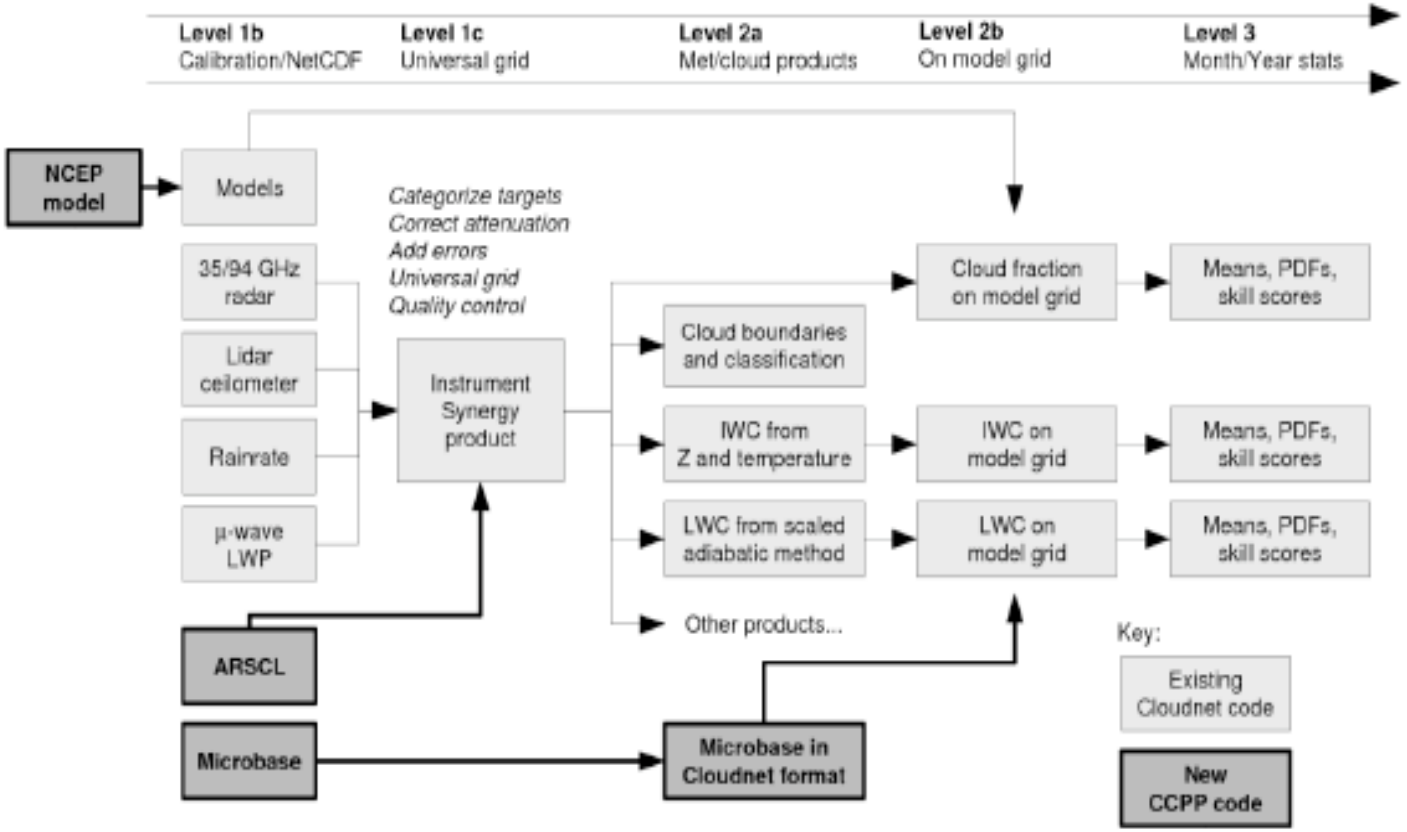
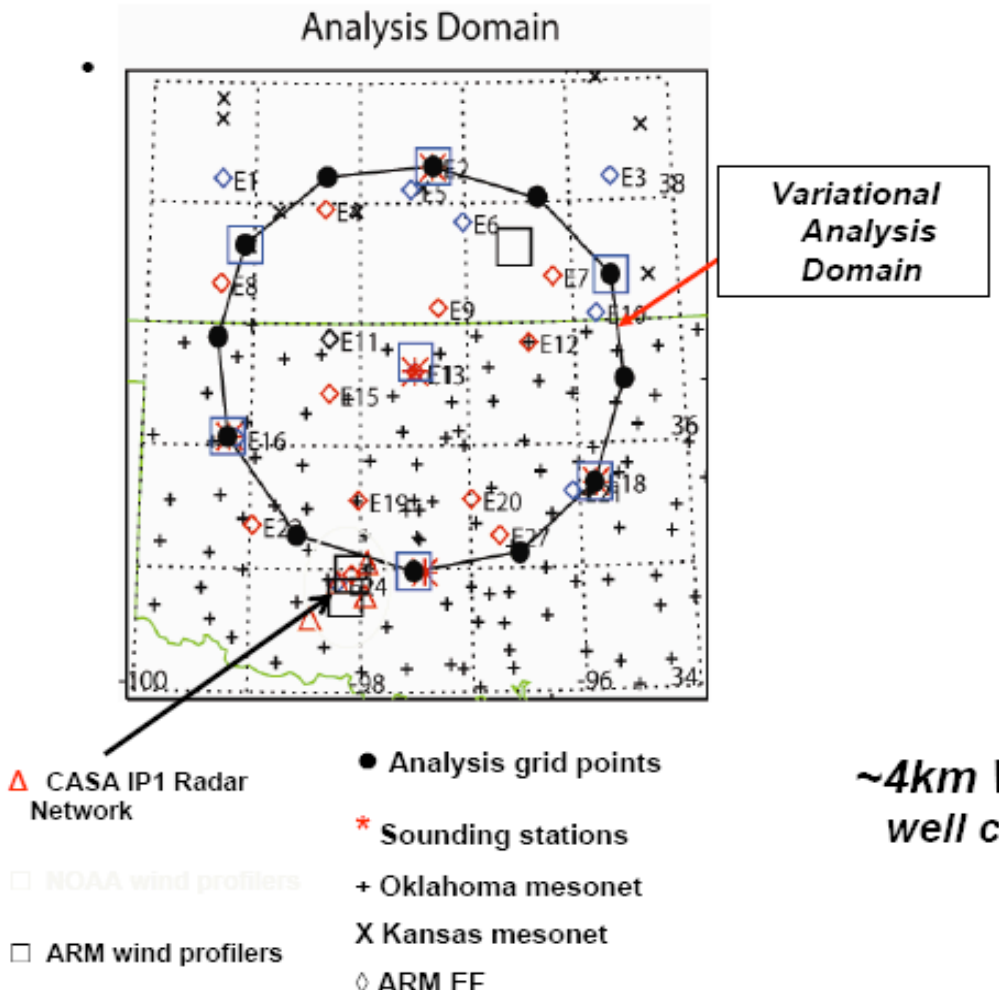


Figure 1. Flowchart of the chain of products produced in the Cloudnet processing system, with the dark-grey boxes and thick arrows indicating the new code that has been written so far in the CCPP project to interface ARM data with Cloudnet software.

SGP Observational Network and Analysis Domain for Large Scale Forcing



~3.5 x 3.5 degree

~ 23 ARM Extended Facilities (EFs)

- *Radiative fluxes*
- *SH, LH*
- *Precipitation*
- *Other surface Meteorology fields (e.g., Ts, Ps)*

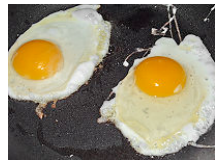
~14 EFs equipped with EBBR (Red)

~9 EFs equipped with ECOR (Blue)

~4km WSR-88D Radar precipitation well covers the domain

(Courtesy of S. Xie)

Metrics Development: Beyond "Fried-Egg" Approaches

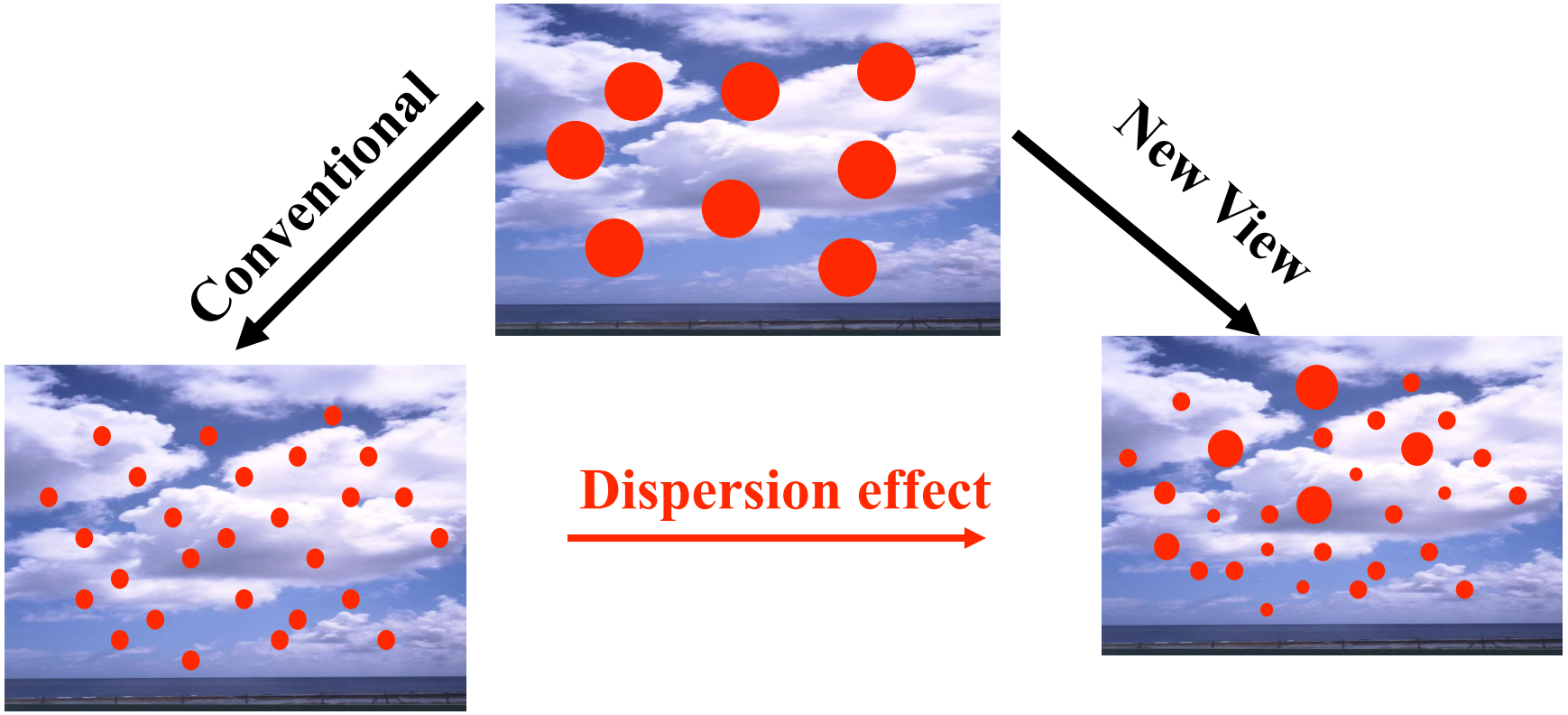


- Taylor diagram
- Relationship quantification
- Covariance matrix & SVD
- Skill metrics
- PDF and structure function
- Relative entropy
- Multiscale clustering
- Outlier identification
- Neural netwwork
- Computer visualization

Table 1. Investigators and Primary Responsibilities

Investigator	Institution	Phone Number	Email	Primary Tasks*
Yangang Liu	BNL	631-344-3266	lyg@bnl.gov	Leadership
Stephen Schwartz	BNL	631-344-3100	ses@bnl.gov	ASP, 3, 5
Warren Wiscombe	BNL/Goddard	631-344-4260	wwiscombe@bnl.gov	ARM, 8
Robert McGraw	BNL	631-344-3086	rlm@bnl.gov	3, 4, 5,6
Wuyin Lin	BNL	631-344-4467	wlin@bnl.gov	1, 3, 4, 5, 7
Andrew Vogelmann	BNL	631-344-4421	vogelmann@bnl.gov	8, 3
Michael Jensen	BNL	631-344-7021	mjensen@bnl.gov	8, 3
Richard Wagener	BNL	631-344-5886	wagener@bnl.gov	8, 3
Dong Huang	BNL	631-344-5818	dhuang@bnl.gov	1, 3, 4, 8
Wei Wu	BNL	631-344-7580	wwu@bnl.gov	1, 3, 4, 5
Surabi Menon	LBNL	510-486-6752	smenon@ibl.gov	1, 3, 4, 7
Susanna Bauer	CU	212-678-5666	sbauer@giss.nasa.gov	1, 3, 4, 7
Minghua Zhang	SBU	631-632-8318	mzhang@stonybrook.edu	1, 3, 4, 5, 7
Marat Khairoutdinov	SBU	6316326339	mkhairoutdinov@stonybrook.edu	2, 3
Anthony Del Genio	GISS	212-678-5588	adelgenio@giss.nasa.gov	1, 3, 4, 5, 7
Ann Fridlind	GISS	212-678-5674	ann.fridlind@nasa.gov	2, 3, 5
Yonghua Chen	CU	212-678-5592	Yc2268@columbia.edu	1, 3, 4, 5, 7
Leo Donner	GFDL	609-452-6562	Leo.j.donner@noaa.gov	1, 3, 4, 5, 7
Zhijin Li	UCLA/JPL	818-393-9058	zhijin.li@jpl.nasa.gov	8, 6, 3, 4
Robin Hogan	UR	44-1183786416	r.j.hogan@reading.ac.uk	1, 3, 4, 5
Roel Neggers	KNMI	31-30-2206868	neggers@knmi.nl	1, 3, 4, 5, 6

New View on Indirect Aerosol Effects



New View:

Indirect Effect = Number Effect + Dispersion Effect